

<b>Research Area 2-1. Estimate impacts of use of dry or hybrid cooling on capital costs, etc.</b>  <b>NB. Also covers:</b> <b>Research Area 2-5. Pilot testing of improved dry cooling concepts to collect performance data</b> <b>Research Area 2.7. Engineering research to improve performance of hybrid cooling systems; and</b> <b>Research Area 2-21. Wet cooling tower condensate capture; reducing consumptive loss across a wet cooling tower.</b>	
Statement of Need	With increasing water scarcity and concurrent increases in electricity demand, dry/hybrid cooling technologies may become more utilized in the U.S. At present, the impacts of widespread adoption are largely unknown; this situation needs to be rectified.
Research Objective	Develop estimates of impacts of use of dry or hybrid cooling on capital costs, energy unit costs, extra capacity needs, carbon emissions, and air quality to identify system requirements for future applications of dry or hybrid cooling and overall system impacts.
Impact/Benefits	High cost of dry cooling, especially retrofits.
Priority	Moderate – DOE prepared baseline analysis as part of 316-b rulemaking process.
Summary Scope of Work	Update DOE baseline analysis to address topics needed by dry and hybrid cooling technology supplier for different regional site conditions, including power plant efficiency, capital and O&M, environmental, resource requirements, etc.
Technical Approach	Develop uniform design, siting, and economic assumptions; assess impacts of dry and hybrid cooling vs. reference cooling system for multiple sites representing a range of water, ambient, and other site conditions.
Lead Investigators (academia, natl. lab, industry, international, partnership)	DOE
Potential Collaborative Govt. Agencies	DOE laboratories
Leverage Opportunities with Existing Programs	Build off previous DOE 316-b study and CEC-EPRI Comparison of Alternate Cooling Technologies Report (EPRI 1005358, 2004)
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Choose assumptions that are representative of regional site conditions.
Estimated Cost	\$250,000
Execution Horizon (early, mid, late)	Early
Schedule/Duration	6-12 months
Level of Development/Level of Maturity at completion	Mature technology
Additional comments	

<b>Research Area 2-2. Examine past work/research on extended surface tubes/fins. Demo fabrication solutions.</b>	
Statement of Need	With increasing water scarcity and concurrent increases in electricity demand, dry/hybrid cooling technologies may become more utilized in the U.S. At present, the impacts of widespread adoption are largely unknown; this situation needs to be rectified.
Research Objective	Extended surface tubes/fins have been investigated in the past; there is a need to conduct a reevaluation of these studies to ascertain the benefits/practicality of such features in dry cooling applications.
Impact/Benefits	Examine past work/research on extended surface tubes/fins. Demo fabrication solutions.
Priority	Moderate to high. Benefit is uncertain, current single-row technology is state-of-the art. Further improvements possible with additional R&D
Summary Scope of Work	Perform baseline analysis to address capability of current extended surface tube design and fabrication technology and potential improvements through R&D. Conduct pilot test of fabrication and operation of new surface design under controlled conditions. Plan and conduct field demonstration.
Technical Approach	Prepare state-of-the-art review of extended surface technology design, fabrication, and performance. Plan R&D program to develop, design, and test improved extended surface tubes/fins. Fabricate prototype extended surface and perform pilot test.
Lead Investigators (academia, natl. lab, industry, international, partnership)	DOE
Potential Collaborative Govt. Agencies	DOE laboratories
Leverage Opportunities with Existing Programs	Build on dry cooling surface supplier experience.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Uncertain cost through from initial demonstration
Estimated Cost	\$100M
Execution Horizon (early, mid, late)	Early
Schedule/Duration	10-15 years for RD&D
Level of Development/Level of Maturity at completion	First of a kind, commercial demo
Additional comments	

**Research Area 2-3. Reduce hot-day impacts on dry and hybrid cooling performance and generation capability.**

**NB. Also covers:**

**Research Area 2-5. Pilot testing of improved dry cooling concepts to collect performance data.**

**Research Area 2-6. Wind/fan impacts. Computational fluid dynamics modeling/detailed data gathering; field-demonstrate solutions.**

Statement of Need	Dry cooling systems cause generation capability penalties under certain atmospheric conditions; these conditions tend to occur during times of high electricity demand. There is a need to develop means to reduce the impacts of these conditions on the generating plant capability.
Research Objective	Reduce hot-day and high-wind impacts on generation capability.
Impact/Benefits	Provide mitigation measures to reduce hot-day and the resulting high-wind impacts on dry cooling performance and increased unit trips.
Priority	High.
Summary Scope of Work	Conduct engineering and economic evaluation of alternate mitigation measures to reduce the impact of hot days and high winds on dry and hybrid cooling tower performance and generation capability. Options include addition of spray cooling, spare wet cooling cell, or barriers, screens, and other structural modifications. Conduct CFD, pilot, and field testing of the most promising measures. Develop plan, solicit host utility, design prototype device, and conduct field demonstration.
Technical Approach	Conduct engineering and economic evaluation of alternate mitigation measures and CFD, pilot, and field testing of the most promising measures. Develop plan, design prototype device, and conduct field demonstration.
Lead Investigators (academia, natl. lab, industry, international, partnership)	DOE, engineering company, dry cooling tower supplier, host utility.
Potential Collaborative Govt. Agencies	DOE national laboratories
Leverage Opportunities with Existing Programs	CEC-EPRI testing of spray-dry enhancement, wind impacts, and modeling of mitigation measures of dry cooling systems.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Finding a host utility for field demo testing.
Estimated Cost	\$100M
Execution Horizon (early, mid, late)	Early
Schedule/Duration	10-15 years for RD&D
Level of Development/Level of Maturity at completion	First of a kind scale-up, commercial demo
Additional comments	

<b>Research Area 2-4. Examine application of dry cooling to nuclear plants.</b>	
Statement of Need	With the prospect of new nuclear generating stations being built in the United States, and the consideration of the considerable water that they consume, there is a need to study the application of dry cooling systems to nuclear generating stations.
Research Objective	Examine application to nuclear plants—preliminary design studies, figure out questions to investigate.
Impact/Benefits	Provide objective data to show impact of substituting dry cooling system to nuclear plant as a function of regional site conditions.
Priority	High. Licensing of new nuclear plants may require evaluation of dry cooling.
Summary Scope of Work	Adapt Research Area #2-1 analysis to apply dry or hybrid cooling to nuclear power plants for different regional site conditions. Address impacts on power plant efficiency, capital and O&M, resource requirements, environmental emissions, etc. Develop ANS/ANSI national standard for application of dry cooling to new nuclear plants.
Technical Approach	Develop uniform design, siting, and economic assumptions; assess impacts of dry and hybrid cooling vs. reference cooling system for multiple sites representing a range of water, ambient, and other site conditions.
Lead Investigators (academia, natl. lab, industry, international, partnership)	DOE, utilities with dry cooling and restricted access to cooling water ,
Potential Collaborative Govt. Agencies	DOE Lab
Leverage Opportunities with Existing Programs	Build off previous DOE 316-b study and CEC-EPRI Comparison of Alternate Cooling Technologies Report (EPRI 1005358, 2004)
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Choose assumptions that are representative of regional site conditions.
Estimated Cost	\$250,000
Execution Horizon (early, mid, late)	Early
Schedule/Duration	6-12 months for evaluation; 2-3 years for ANS/ANSI standard.
Level of Development/Level of Maturity at completion	Mature technology
Additional comments	

<b>Research Area 2-8. Wet surface air cooling demonstration.</b>	
Statement of Need	Wet surface air cooling (WSAC) offers considerable benefits. WSAC offers an alternative to dry cooling using a deluge of poor quality water to cool water in a circulating cooling water line. There is a need to demonstrate such concepts under real-world conditions to develop cost and performance baselines.
Research Objective	Wet air surface cooling demonstration.
Impact/Benefits	May provide a less expensive alternative to dry cooling.
Priority	High.
Summary Scope of Work	Scale-up wet surface air cooling unit to larger capacity. As needed, conduct CFD, pilot, and field testing of alternate designs. Develop plan and conduct field demonstration.
Technical Approach	Evaluate scale-up of Niagara Blower wet surface air cooling unit tested at San Juan Plant, via engineering and economic evaluation of alternate designs. As needed, conduct CFD, pilot, and field testing of alternate designs. Develop detailed plan and solicit host site for field demonstration. Design and evaluate prototype for field demonstration. Plan and conduct field demonstration.
Lead Investigators (academia, natl. lab, industry, international, partnership)	DOE, Niagara Blower, utilities with restricted access to clean cooling water.
Potential Collaborative Govt. Agencies	DOE national laboratories
Leverage Opportunities with Existing Programs	DOE Zero-Net evaluation of WSAC at San Juan
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Finding a host utility for demo testing.
Estimated Cost	\$100k
Execution Horizon (early, mid, late)	Early
Schedule/Duration	10-15 years for RD&D
Level of Development/Level of Maturity at completion	First of a kind scale-up, commercial demo
Additional comments	

<b>Research Area 2-9. Examine compatibility of materials in cooling systems with unconventional waters.</b>	
Statement of Need	As water becomes increasingly scarce or expensive, there may arise the need to use unconventional waters in cooling systems. Thus, there is a need to examine the compatibility of materials and unconventional waters.
Research Objective	Examine compatibility of materials in cooling systems with unconventional waters <ul style="list-style-type: none"> <li>• Determine impacts of using desalination concentrate as cooling medium</li> <li>• Identify what water quality components are most detrimental when used in hybrid cooling systems, and the mechanisms of adverse impact</li> <li>• Research on cooling tube, etc. materials that can handle produced water chemistries without degradation</li> </ul>
Impact/Benefits	Existing plants can determine whether to use the impaired water stream economically. Overall impact of pursuing all three objectives would free up water for other purposes than use in power plants. Using the waste stream out of desalination or other treatment facilities for a useful purpose. Understanding compatibility of materials and water qualities would aid in development of new power plants.
Priority	High
Summary Scope of Work	Testing of existing materials' and coatings' ability to be used with impaired waters. Determine, in general, given where power plants are estimated to be, how much water savings would there be by using desalination plant concentrate, due to increased energy intensity needed to successfully use desalinated water. That is, complete a feasibility study of water and energy efficiency to develop these water sources.
Technical Approach	Identify testing protocols to study materials and coatings. Consider using tribology knowledge as starting point to develop more durable materials for use under corrosive conditions. Identify regulatory constraints, materials constraints of addressing corrosion issues.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Academia, industry labs
Potential Collaborative Govt. Agencies	EPA, DOE, NIST, National Association of Corrosion Engineers, NSF
Leverage Opportunities with Existing Programs	Yes
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	EPA UIC regulations; there is no underground injection well regulated to handle wastewater.
Estimated Cost	\$10M
Execution Horizon (early, mid, late)	Mid
Schedule/Duration	2007-2017
Level of Development/Level of Maturity at completion	Complete feasibility study.
Additional comments	

<b>Research Areas 2.10 and 2.11. Conduct health risk assessments of sewage water/effluent use in cooling towers. Reduce aerosol of reuse water in power plant cooling to reduce health impacts. Demonstrate better drift eliminators to reduce health risks.</b>	
Statement of Need	<p>At this time, there is no need to develop technologies to address aerosols and air quality in power plants using unconventional water resources, but a risk assessment must be performed to determine the need for such technologies.</p> <p>The potential use of treated sewage waters in cooling systems raises some public health issues and concerns. To this end, there is a need to conduct health risk assessments to ease the potential use of this unconventional water resource.</p> <p>There is a health effects-driven need to reduce the escapes of unconventional waters from plant cooling systems. To this end, there is a need to reduce both the aerosolization of waters and to develop better drift eliminators.</p>
Research Objective	<p>Conduct health risk assessments of sewage water/effluent use in cooling towers.</p> <p>Reduce aerosol of unconventional waters in power plant cooling to reduce health impacts.</p> <p>Demonstrate better drift eliminators to reduce health risks.</p>
Impact/Benefits	Better understanding health and environmental risks posed to power plant workers and general public.
Priority	Low-mid
Summary Scope of Work	Health, safety and environmental risk assessment based on current knowledge.
Technical Approach	<p>Perform health and environmental assessment of the impacts of aerosols and drift from unconventional water use in cooling towers.</p> <p>Identify emerging contaminants in unconventional waters and examine how they behave in cooling systems. In this case, unconventional water includes sewage waters.</p>
Lead Investigators (academia, natl. lab, industry, international, partnership)	EPA, NIOSH, DOE, NIES
Potential Collaborative Govt. Agencies	NIOSH, NIES, DOE
Leverage Opportunities with Existing Programs	Yes
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Level of detection to measure contaminants in cooling water drift may not be low enough to examine potential risks.
Estimated Cost	\$100-500K
Execution Horizon (early, mid, late)	Early
Schedule/Duration	2007-2012
Level of Development/Level of Maturity at completion	
Additional comments	No technical research needed, but risk assessments to workers and general public should be pursued.

<b>Research Area 2-12. Cycles of concentration—Characterization of waters, new treatment techs to increase number of cooling cycles.</b>	
Statement of Need	There is a need to update the design and operating guidelines originally developed for zero discharge power plants to address the use of unconventional waters in the new technology for treating of waters at power plants seeking to operate at high cycles of concentration.
Research Objective	<p>Define the availability of unconventional water resources, their quality and composition. Preferably we would determine a supply of consistent quality and availability for power cooling.</p> <p>Develop treatment systems to increase quality of water in cooling towers – it needs to be more cost efficient. We need research to increase the efficiency and selectivity of water treatment processes to increase the number of cooling cycles. Improve performance and cost. Streams are side stream, blowdown and processes.</p>
Impact/Benefits	Improved water availability and impaired water allocation.
Priority	High
Summary Scope of Work	Assess the variability and availability of unconventional waters and technologies to utilize it. Identify means of increasing cycles of concentration.
Technical Approach	<p>Sequential studies to:</p> <ol style="list-style-type: none"> <li>1. Perform a scoping study to identify things that we would want to do to increase the cycles of separation, e.g. membranes to separate out solids, energy efficient approaches.</li> <li>2. Determine circumstances under which membranes or other separation technologies would be more operationally viable, and make sludge a valuable byproduct.</li> <li>3. Create a set of best practices manuals for unconventional water use that accounts for regional variation.</li> </ol>
Lead Investigators (academia, natl. lab, industry, international, partnership)	Interdisciplinary team of USGS, universities, DOE national labs, EPRI
Potential Collaborative Govt. Agencies	USGS and DOE
Leverage Opportunities with Existing Programs	Yes
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Effluent stream discharge issues, study the economic and regulatory tradeoffs between using impaired waters and freshwaters. There is challenge in introducing flexibility into the regulatory structure to account for multienvironmental media impacts (life cycle analysis).
Estimated Cost	\$1-500M
Execution Horizon (early, mid, late)	Early
Schedule/Duration	2007-2012
Level of Development/Level of Maturity at completion	
Additional comments	There is ongoing research underway at DOE that focuses on increasing cycles of concentration; this effort should build upon this existing work.

<b>Research Area 2-14. Utilize waste heat to treat water.</b>	
Statement of Need	Unconventional waters will requires some degree of treatment before they can be used in most cooling systems. Given the availability of waste heat in thermoelectric plants, there is a need to examine the development of water treatment processes that effectively utilize waste heat.
Research Objective	Develop unconventional water treatment processes that utilize waste heat.
Impact/Benefits	Reduce energy consumption of water treatment.
Priority	Medium
Summary Scope of Work	Quantifying amounts of heat per unit process and source within a power plant, determine whether there is enough to purify water to desired purity. Redesign technologies to double-task at collecting heat and purifying water, for example, cooling towers to collect heat and purify water. Set goals for collecting waste heat and using it to clean water.
Technical Approach	Areas to investigate further are waste heat for use in desalination, redesigning cooling towers to purify water – develop conceptual designs first and moving on from there.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Industry, national laboratories
Potential Collaborative Govt. Agencies	DOE, EPA
Leverage Opportunities with Existing Programs	Yes
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Infrastructure issue; you need to be able to store water or waste heat. Second law of thermodynamics
Estimated Cost	\$5M
Execution Horizon (early, mid, late)	Mid
Schedule/Duration	2007-2017
Level of Development/Level of Maturity at completion	Pilot program
Additional comments	

<b>Research Area 2-16. Evaluate the potential for using in ground cooling to reduce capital costs and evaporative loss.</b>	
Statement of Need	There is a need to investigate the use of in-ground cooling at thermoelectric plants.
Research Objective	Evaluate the potential for using in-ground cooling to reduce capital costs and evaporative loss.
Impact/Benefits	Lower capital cost/lower water usage; Might be more applicable to distributed generation type sites since heat load rate would be lower.
Priority	Low priority item.
Summary Scope of Work	A study on the overall efficiency of prototypic systems (including geographical factors and appropriate generation size) for the purpose of determining any economic advantage and environmental impacts.
Technical Approach	<p>Literature review to determine appropriate plant size and configuration for different geophysical parameters; followed by high level economic study and EIS; Some determination of financial risk.</p> <p>If literature review indicates the need for technological innovations, an appropriate research plan should be outlined.</p>
Lead Investigators (academia, natl. lab, industry, international, partnership)	Academia, but will require interdisciplinary program participation.
Potential Collaborative Govt. Agencies	DOE-FE, EPA
Leverage Opportunities with Existing Programs	TBD; Determination of maximum heat load rates may be able to use analyses done for Yucca Mountain.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Potential state by state issues; probably no governing existing regulations; possibly limited geographic areas of applicability.
Estimated Cost	\$100,000
Execution Horizon (early, mid, late)	Academic study could be done in the early term; depending on results priorities for follow work will need to be determined.
Schedule/Duration	One year
Level of Development/Level of Maturity at completion	No technologies will come out of this study.
Additional comments	There is a consensus that this idea has extremely limited potential.

<b>Research Area 2-18. Steam turbine Improvements.</b>	
Statement of Need	To reduce cooling water consumption, there is a need to develop improved steam turbines.
Research Objective	Steam turbine improvements: <ul style="list-style-type: none"> <li>• Improved modeling of steam turbines (reduce heat load)</li> <li>• Steam Turbine materials</li> </ul>
Impact/Benefits	The water efficiency from this area is mainly from the reduced heat load and increased thermal efficiency of the turbine. However, advanced steam turbine design is being funded under several existing DOE programs: Clean Coal Initiative, Future Gen (hydrogen), and CHP.
Priority	Medium Priority for energy water nexus because of existing funded programs.
Summary Scope of Work	Current programs are mainly cost-shared arrangements with industry leadership in both development and demonstration programs.
Technical Approach	TBD based on existing program objectives.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Industry, Academia, and national laboratories
Potential Collaborative Govt. Agencies	None
Leverage Opportunities with Existing Programs	The proposed program is highly leveraged by existing programs. The main area for the EW Nexus team would be in an integrative role for overall water efficiency.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Technical challenges involving high performance materials in extreme environments; advanced high performance computing for better modeling.
Estimated Cost	Current programs are funded in the \$50 million range for the total program not including cost share.
Execution Horizon (early, mid, late)	Early
Schedule/Duration	TBD
Level of Development/Level of Maturity at completion	Existing programs are at a high level of development and will lead to at least some deployable products.
Additional comments	There is a need to determine the actual water efficiency gain that could arise from this increased thermal efficiency program.

<b>Research Area 2-19. Heat recovery from condenser water discharge.</b>	
Statement of Need	In a further effort to improve overall efficiency, there is a need to investigate recovery and reuse of heat from condenser water discharge.
Research Objective	Heat recovery from condenser water discharge.
Impact/Benefits	Impact and benefits need to be defined for specific recovery techniques and reuse applications; Many studies have been done in these areas and have identified such benefits but the economics and technology have not been demonstrated on a commercial scale.
Priority	Low
Summary Scope of Work	There are two scopes of work: water reuse and energy recovery. Water reuse involves a value proposition specific to the intended reuse application. Energy recovery is specific to the type, size, and location of the generation facility.
Technical Approach	Review existing literature and quantify potential water efficiency gain.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Academia; national laboratories
Potential Collaborative Govt. Agencies	EPA, USDA
Leverage Opportunities with Existing Programs	Future Gen?
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Regulatory constraints have a potentially large impact on the value proposition for both reuse and recovery.
Estimated Cost	\$100,000
Execution Horizon (early, mid, late)	Early
Schedule/Duration	One Year
Level of Development/Level of Maturity at completion	Potential tradeoffs should be well understood.
Additional comments	

<b>Research Area 2-20. Computational modeling of power plant design/ efficiencies, reduce heat load to environment and surface water.</b>	
Statement of Need	Advanced computational modeling may allow higher efficiency plants, thus limiting water consumption or producing greater volumes of product per unit of water.
Research Objective	Developed improved computational models of power plant design/efficiencies in an effort to reduce heat load to environment and surface water.
Impact/Benefits	Advanced integrated models have the potential to identify advanced equipment, sensors, monitoring, and control systems that would significantly increase thermal/water efficiency. There is also the possibility that first principles modeling could identify breakthrough materials.
Priority	High
Summary Scope of Work	This needs to be further refined with a first step review of existing models. Ultimately, this will actually require a sub-road map because the area is so broad although this group recommends an initial focus on tightly integrated whole plant models.
Technical Approach	TBD
Lead Investigators (academia, natl. lab, industry, international, partnership)	National laboratories; Academia; International
Potential Collaborative Govt. Agencies	NSF, EPA
Leverage Opportunities with Existing Programs	DOE-SC (ASCR); Stockpile Stewardship
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Requires immediate startup if it is to be effective. Technical challenges could be severe. Need to demonstrate acceptability to regulatory agencies.
Estimated Cost	Based on similar programs, funding in the \$2-5 million per year range will be needed.
Execution Horizon (early, mid, late)	Early
Schedule/Duration	Five Year starting in the near future
Level of Development/Level of Maturity at completion	TBD; however, it will be deployable.
Additional comments	

<b>Research Area 2-21. Cooling tower condensate capture/Reducing consumptive loss across a cooling tower.</b>	
Statement of Need	Capturing cooling tower condensate will reduce a plant's fresh water withdrawals.
Research Objective	Cooling tower condensate capture/Reducing consumptive loss across a cooling tower.
Impact/Benefits	These will be determined underneath a NETL funded project.
Priority	Medium
Summary Scope of Work	Based on results, determine if technology needs to be further refined.
Technical Approach	TBD
Lead Investigators (academia, natl. lab, industry, international, partnership)	National laboratory; Industry
Potential Collaborative Govt. Agencies	None
Leverage Opportunities with Existing Programs	Existing NETL Program
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Intellectual Property issues
Estimated Cost	\$25,000
Execution Horizon (early, mid, late)	On going
Schedule/Duration	Two years /one month (Current field test project has just started this CY)
Level of Development/Level of Maturity at completion	Very mature
Additional comments	<b>Marley Cooling Technologies, Inc.</b> , will determine the benefits of its patented Air2Air™ condensing technology as applied to a cooling tower by adding its new technology to an existing evaporative cooling tower at a coal-fired power plant to be selected. The company will study and quantify the amount of water recovery from the normal evaporation process and subsequently determine the performance and operating parameters of the condensing technology. The ultimate benefit to be explored will be the water savings potential of the condensing technology. (DOE share: \$650,106; industry cost share: \$162,527; project duration: 18 months)

<b>Research Area 2-22. Research and development to reduce water loss in scrubbers.</b>	
Statement of Need	There is a need to reduce the volume of water lost in the operation of scrubbers.
Research Objective	Reduce water loss in wet SO <sub>2</sub> scrubbers that is either evaporated or trapped in solids.
Impact/Benefits	Reduce consumptive water use for current and future operations of wet scrubbing systems. Scrubbing capacity expected to triple over the next 20 years due to new air-quality (SO <sub>2</sub> ) regulations.
Priority	Medium: DOE has initiated research in this area already.
Summary Scope of Work	Develop proof-of-concept laboratory investigations followed by pilot-scale/full-scale demonstrations to reduce and/or recover evaporative loss during scrubbing.
Technical Approach	<ul style="list-style-type: none"> <li>Design hardware to reduce temperature of flue gas entering scrubber to minimize evaporative loss. <ul style="list-style-type: none"> <li>Identify most cost-effective heat-transfer medium (e.g., ammonia, water, air)</li> </ul> </li> <li>Develop system that condenses and recovers evaporated water downstream of SO<sub>2</sub> scrubber.</li> </ul>
Lead Investigators (academia, natl. lab, industry, international, partnership)	DOE NETL, EPRI (CO <sub>2</sub> ), Industry
Potential Collaborative Govt. Agencies	DOE
Leverage Opportunities with Existing Programs	NETL has a project to look at reducing temperature of incoming flue gas. Possible collaboration with existing CO <sub>2</sub> capture (DOE, EPRI).
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Air-quality regulations have been passed that will drive increased use of SO <sub>2</sub> scrubbing technologies. New technologies to reduce water use could negatively impact performance of scrubber (regulatory/compliance risk for host sites).
Estimated Cost	R&D: \$7M over 7 years Demonstration: \$25M (federal share) for full-scale demonstration
Execution Horizon (early, mid, late)	Early for R&D; mid for demonstration
Schedule/Duration	R&D: 7 years (preliminary work is underway) Demonstration: 3-5 years following R&D
Level of Development/Level of Maturity at completion	Commercial product after 10-12 years.
Additional comments	

<b>Research Area 2-23. Address issues of advanced scrubbing to reduce CO2.</b>	
Statement of Need	Need to conduct assessment of impact of CO2 capture technology on water consumption and use.
Research Objective	Understand water consumption and use for CO2 capture technologies.
Impact/Benefits	If there is a significant impact from CO2 capture technologies on water consumption, research may help to reduce the consumption.
Priority	Medium
Summary Scope of Work	An assessment of CO2 capture technologies and their potential impact on water use and consumption.
Technical Approach	Conduct assessment using literature search, dialog with experts developing CO2 capture technologies, and data evaluation.
Lead Investigators (academia, natl. lab, industry, international, partnership)	National laboratories
Potential Collaborative Govt. Agencies	DOE
Leverage Opportunities with Existing Programs	DOE and EPRI have CO2 capture technology projects
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	People who are developing CO2 capture technologies may not be willing to share data and information regarding these processes.
Estimated Cost	\$200K
Execution Horizon (early, mid, late)	Early
Schedule/Duration	1 year
Level of Development/Level of Maturity at completion	Good understanding of CO2 capture technology impact on water use and consumption.
Additional comments	

<b>Research Areas 2-24 and 2-25. Water-quality issues and scrubbers.</b>	
Statement of Need	<p>Companies have already investigated scrubber chemistry and reuse of scrubber water (low priority).</p> <p>For scrubbers that are used to also capture mercury and other trace metals, the fate of these species (concentration and where it's going) needs to be understood.</p>
Research Objective	Develop an understanding of mercury and other trace-metal fate and transport in power-plant wastewater streams (e.g., flue-gas treatment, fuel handling, solid-waste disposal).
Impact/Benefits	Results of this effort will provide meaningful information for regulatory/policy decision making.
Priority	<p>Relative to water availability, the priority of this effort is low/medium.</p> <p>Relative to regulatory/policy this effort is high.</p>
Summary Scope of Work	Create database with concentrations and amount of mercury and trace-metals in power-plant process waters. Develop better detection and treatment technologies as needed.
Technical Approach	<ul style="list-style-type: none"> <li>• Develop an understanding of mercury and other trace-metal fate and transport in power-plant wastewater streams (e.g., flue-gas treatment, fuel handling, solid waste disposal). Compile existing data on measurements of fate and transport of mercury and other species in plant process waters.</li> <li>• Identify gaps in measurements and desired information.</li> <li>• Conduct field sampling and analytical efforts to fill gaps.</li> <li>• Create associated database of concentrations and amounts.</li> <li>• Develop better detection and treatment technologies as needed.</li> </ul>
Lead Investigators (academia, natl. lab, industry, international, partnership)	Federal/private sector collaboration.
Potential Collaborative Govt. Agencies	DOE
Leverage Opportunities with Existing Programs	DOE/NETL power-plant water R&D program. EPRI PICES program (sampled all streams (air, water, and solids) in power plant (created database)).
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	We don't know if analytical techniques are sufficient to detect levels of mercury and other species in the process streams. Industry reluctance to participate because of sensitivity to future regulations.
Estimated Cost	<ul style="list-style-type: none"> <li>• Initial data compilation (\$100K)</li> <li>• Additional sampling per plant (\$300K-\$500K, as needed)</li> <li>• Database compilation and maintenance (\$300K)</li> <li>• R&amp;D to develop advanced treatment or detection technologies (\$1M-\$2M per project, as needed)</li> <li>• Full-scale demonstration of advanced technologies (\$1M-\$5M per demo)</li> </ul>
Execution Horizon (early, mid, late)	Early for data compilation, mid for sampling, and late for R&D and Demo.
Schedule/Duration	2007-2013
Level of Development/Level of Maturity at completion	Ready for commercial deployment, if needed.
Additional comments	

<b>Research Area 2-26. Improved intake designs that reduce fish and aquatic species mortality.</b>	
Statement of Need	As new plants are developed, and as existing plants come into compliance with 316b rules, and new intake structures are installed, there is a need to demonstrate improved intakes that offer reduced fish and aquatic species mortality.
Research Objective	A large number of fish protection devices have been identified, but few have been evaluated for specific species and water bodies. There is a research need to demonstrate the engineering efficacy of these devices and the ecosystem impact in a variety of water bodies.
Impact/Benefits	For a specific site that may be restricted, the high economic cost of some intake options may force construction of very costly cooling systems such as dry cooling or hybrid cooling. Benefits would be economic savings and reduced mortality of fish and aquatic populations, many of which are threatened or endangered species.
Priority	High (given the large number of existing facilities that need to come into compliance with 316b regulations, as well as proposed new facilities in areas with low water availability).
Summary Scope of Work	A cooperative study is needed including fishery scientists and energy sector experts (e.g. cooling system design engineers) to evaluate impacts associated with intake protection devices on fish and shellfish mortality. Mortality estimates should be synthesized with population and ecosystem models to estimate the impacts on population growth, especially of threatened species.
Technical Approach	A series of experimental sites, which represent a broad range of water bodies, should be identified for evaluation of intake protection devices. At each site, researchers would conduct experiments with pre- and post- impact conditions related to the specific intake device. Finally, ecosystem modelers should incorporate the population impacts of different intake options to fully evaluate designs and operation.
Lead Investigators (academia, natl. lab, industry, international, partnership)	EPRI, federal power authorities
Potential Collaborative Govt. Agencies	DOE/NETL, EPA, USGS, NOAA, FWS, Academia
Leverage Opportunities with Existing Programs	EPRI existing 316b program area. EPA Office of Water. USGS work with federal entities (BPA, BOR, ACOE) that develop better understanding of fish behavior.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Costs could be substantial depending on size of cooling system. Competing concerns between intake needs and downstream impacts such as heating. Few technical challenges.
Estimated Cost	>\$10 million
Execution Horizon (early, mid, late)	Mid
Schedule/Duration	2010 – 2020
Level of Development/Level of Maturity at completion	A relatively good understanding of the ecological impact of different, and most promising, intake technologies.
Additional comments	